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Miniaturized gyrocompass

Harold G. Britton, Jr.

JUNE 1982

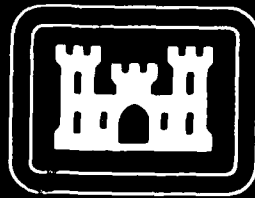
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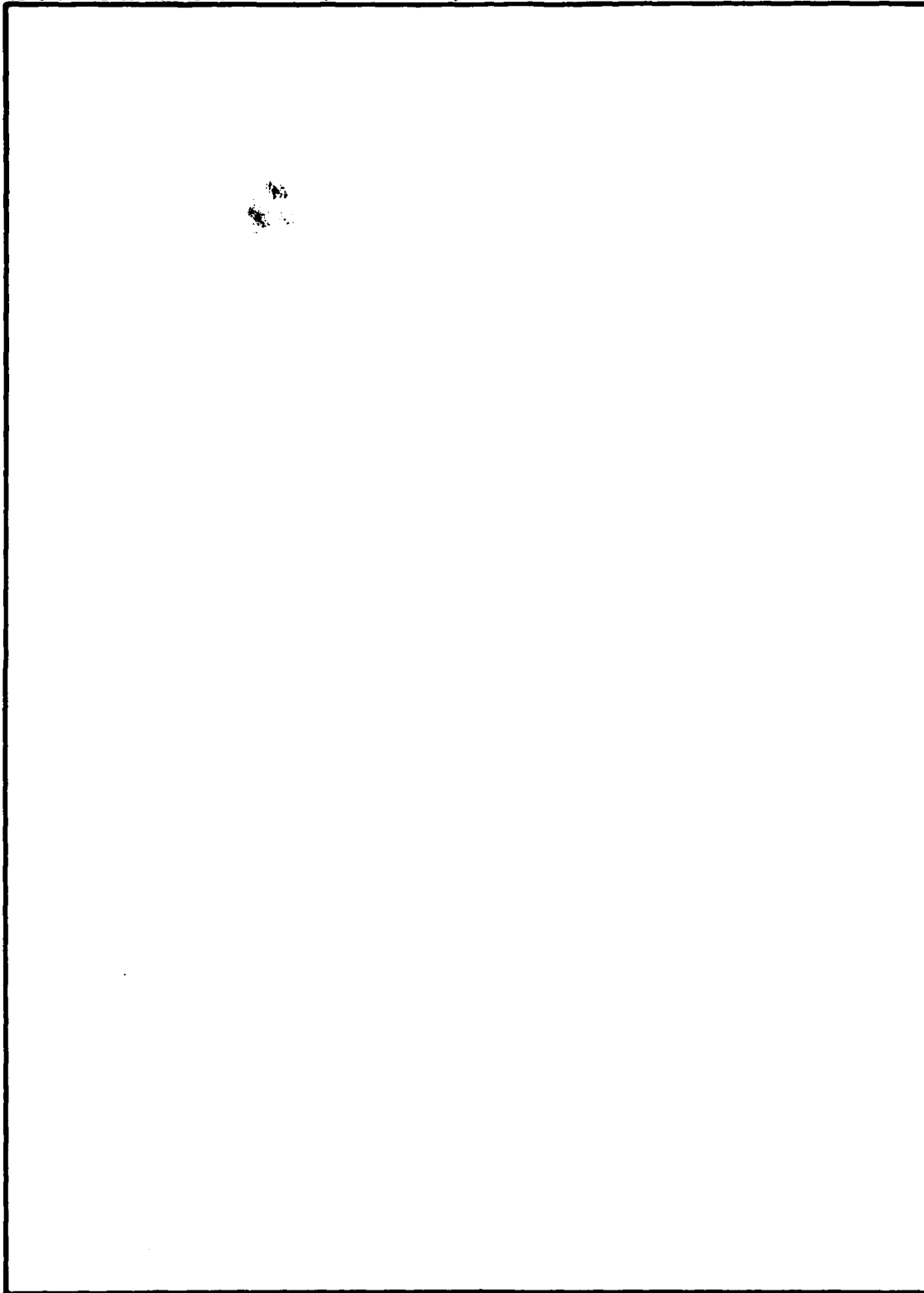
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report summarizes the exploratory development efforts that were directed toward using gyro technology to define true north to an accuracy of 2 milli-radians within 2 minutes of time. Several different approaches were explored. The report concludes that a device could be fabricated that would meet stated accuracy and response times.		

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PREFACE

This study was conducted under DA Project 4A762707A855, Task A0, Work Unit 0003, "Miniaturized Gyrocompass."

The study was done during the period October 1975 - July 1981 under the supervision of Mr. P. J. Cervarich, II, Chief, Inertial Optical Survey Equipment Branch; Mr. J. G. Armistead, Chief, Surveying and Engineering Division; and Mr. C. R. Friberg, Jr., Director, Topographic Developments Laboratory.

COL Edward K. Wintz, CE, was Commander and Director, and Mr. Robert P. Macchia was Technical Director of the Engineer Topographic Laboratories during the report preparation.

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MINIATURIZED GYROCOMPASS

INTRODUCTION

The investigations on a miniaturized gyrocompass were initiated in FY 76 as a 6.2, Exploratory Development effort. The objective was to examine the state-of-the-art, user requirements, and operational concepts for azimuth-measuring equipment and to prepare an evaluation report for a proposed miniaturized gyrocompass. The effort was to include estimates of size, weight, accuracy, power requirements, and observing times. This report is a summary of that effort, including findings of user requirements, evaluation of a brassboard model miniaturized gyrocompass, and the results of the evaluation of several prototype miniaturized gyrocompasses.

BACKGROUND

The Surveying Instrument -- Azimuth, Gyro, Lightweight (SIAGL) was designed, developed, tested, and type-classified in 1972 under the direction of the Engineer Topographic Laboratories (ETL) based upon a DA-approved Qualitative Materiel Requirement (QMR) for the Field Artillery. The SIAGL was then described as a lightweight (weighing 45 pounds), rapid (20-minute reaction period), and accurate (0.2 cos latitude mils) true north azimuth-determining device. Its predecessor, the Autonetics Baseline Equipment (ABLE) weighed more than 150 pounds, was extremely sensitive to vibrations, and typically required an observation period of over one hour. The SIAGL greatly reduced the logistics requirements and operational constraints associated with the ABLE and is currently a standard item in the Army inventory used by Field Artillery organizations for survey, fire direction, and target acquisition purposes.

A report from the Artillery Systems Study Group, Task Force Battleking (1974), identified certain deficiencies in survey equipment. For example, extension of survey control was inherently too slow even though the accuracy of current survey techniques was satisfactory. The SIAGL that would replace the ABLE orientor would not appreciably speed up the survey process. Another deficiency pointed out in the Battleking report was the lack of a small north-seeking gyro for use by the forward observer and similar functional groups as envisioned for example in figure 1. The study further recognized the lack of adequate azimuth-determining capability with future externally referenced electronic positioning systems, such as the Global Positioning System (GPS) and Position Location Reporting System (PLRS). In March 1975, the U.S. Army Field Artillery School



Figure 1. MINIATURIZED GYROCOMPASS CONCEPT.

requested an early investigation into the direction-determining technology to identify which technology would lead to the development of a lightweight, rugged, quick-reaction device for determination of azimuth without reliance on magnetism.

INVESTIGATION

User Survey - In October 1975, ETL conducted a survey of user requirements and operational concepts for a miniaturized gyrocompass to assist in this technology investigation. Responses from the various Army schools and organizational units provided a variety of requirements. The responses focused on the need for a small instrument weighing less than 7 pounds, having an accuracy between 1 and 3 mils and a reaction time of less than 7 minutes. Several responses included vehicle applications in both static and dynamic modes of operation.

Initial Study Efforts - The major area of concern was to establish the feasibility of developing an instrument with the following basic design features: (1) 1 to 3 mils accuracy, (2) 3 to 7 pounds weight, and (3) 3 to 7 minutes reaction time. Limited effort was expended in the type or method of an azimuth-transfer device from the instrument -- for example, a porro prism or a telescope. The initial feasibility model was designed to be mounted atop a Wild T-16 standard Army theodolite with automatic alinement of the azimuth instrument with the optical bore sight of the theodolite. Thus, the theodolite provided an accurate and reliable means for testing and evaluating the miniaturized gyrocompass. The instrument was to be compactly packaged for convenient operation, to be transportable by one man, and to be operable under all-weather, day-night conditions.

Litton Contract. A contract was awarded to Litton Systems, Inc. for a feasibility model miniaturized gyrocompass, referred to as a Miniaturized North Reference Unit (MINRU), in September 1977. The fundamental goal was to demonstrate by analysis, design, and testing, the feasibility of achieving a lightweight, reliable, rugged, and low-cost, true-north reference unit suitable specifically for use in Army tactical environments by Artillery forward observers, and more generally whenever an accurate north reference is required.

The MINRU, figures 2, 3, and 4, was tested and evaluated by ETL during 1978 to assess its basic performance characteristics and capabilities. The tests included the following categories: heading sensitivity, case tilt, accuracy, mechanical stability, and temperature. However since the MINRU was not a militarized item, environmental

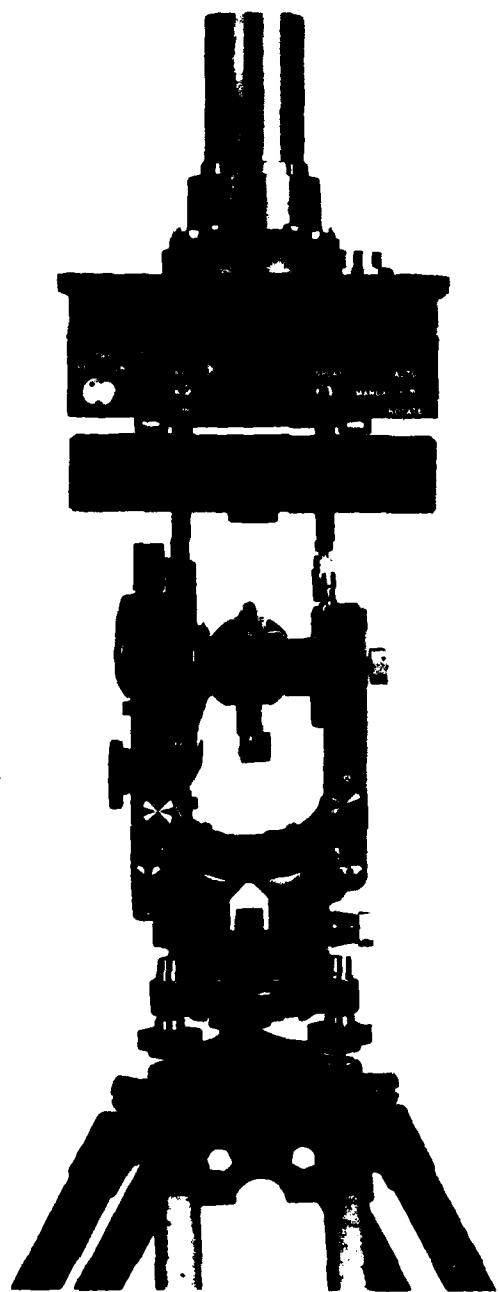


Figure 2. LITTON FEASIBILITY MODEL (MINRU), FRONT VIEW.

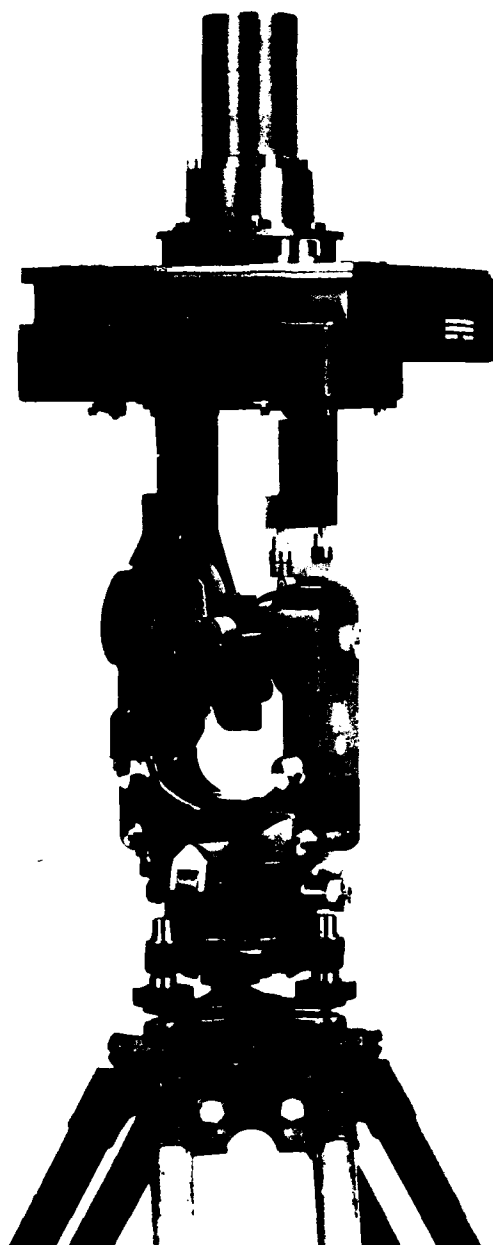


Figure 3. LITTON FEASIBILITY MODEL (MINRU), THREE-QUARTER VIEW.

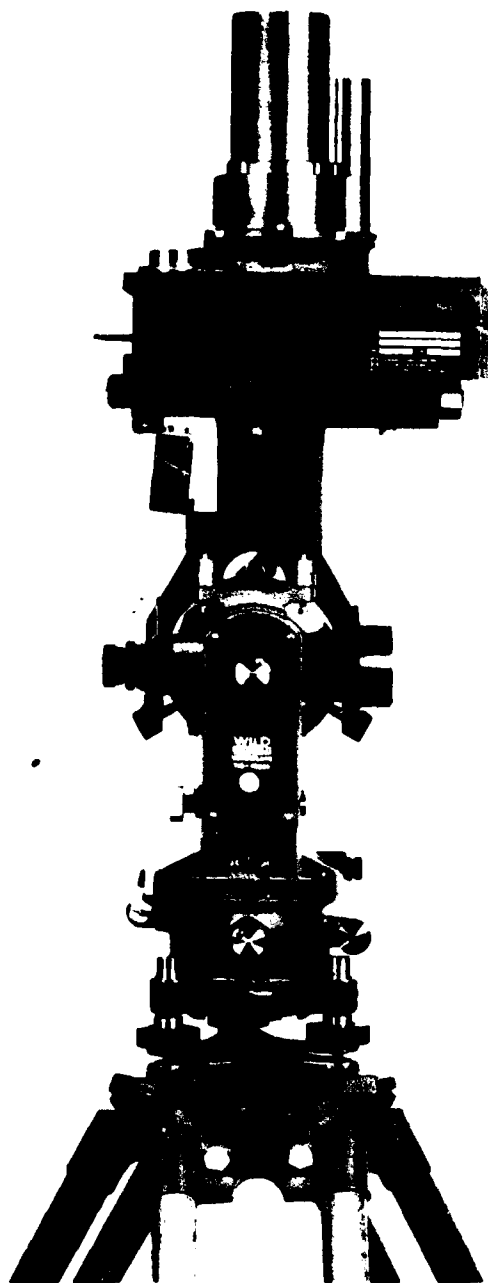


Figure 4. LITTON FEASIBILITY MODEL (MINRU), SIDE VIEW.

testing was performed against reduced specifications. Additional data are available in the final report prepared by Litton for ETL.

North-Seeking Gyrocompass (NSG). In 1978, this agency was assigned the responsibility for the procurement, tests, and evaluation of a North-Seeking Gyrocompass (NSG), a small, quick-reacting, vehicular-mounted azimuth reference device, for the Fire Support Team Vehicle (FISTV). Two contracts were subsequently awarded in September 1978 to Sperry Gyroscope and Northrop Corporation in response to Request for Proposal (RFP) DAAK70-78-R-1763. Because at that time the NSG was to be mounted to a vehicle hull, the RFP specified a gimballed, self-leveling mounting fixture with the interface between this fixture and the NSG to be compatible with the Navy's North-Finding Module (NFM) design currently under development for the Modular Universal Laser Equipment (MULE). The two competing contractors for the Navy's NFM were at that time Sperry Gyroscope and Litton Systems, Inc.

The Sperry contract for two NSG's, including gimballed mounts for use with their existing NFM design, was fully funded. The Northrop contract, also for two NSG's and gimballed mounts, addressed a unique design approach having potential advantages over more conventional designs. This new approach had been tested only in a laboratory configuration. Because of limited funds, the contract with Northrop was incrementally funded. In September 1979, ETL was instructed to terminate efforts to develop a hull-mounted NSG, owing to a decision that the NSG would have to be mounted within an articulated head and be operated remotely. In response to this decision, the Northrop contract was terminated.

The Sperry contract was completed and hardware was delivered to ETL for test and evaluation. At the same time, two NFM's, one from Litton and one from Sperry, were delivered to ETL as previously arranged with the Naval Weapons Center, China Lake, California. All of these units -- three Sperry NFM's and one Litton NFM -- were evaluated and tested by ETL. The gimballed mount delivered by Sperry was used in limited vehicle tests of the NFM's. Details of laboratory tests and their results are contained in

¹ Litton Guidance and Control System, The Design, Modification, Fabrication, and Test of a Prototype Minaturized North Reference Unit (MINRU), US Army Engineer Topographic Laboratories, Fort Belvoir, VA., ETL-0276, March 1979, AD-B061 822L.

Sperry's report.² The summary results of these tests and the MINRU sts have been extracted from the referenced reports and are presented as follows:

Summary of Test Results

	Litton MINRU	Litton NFM	106	Sperry NFM's	
				107	108
Weight (lbs.)	6.0	5.5	3.7	3.7	3.7
Volume (cu. in.)	N/A*	223.4	158.8	158.8	158.8
Response (sec.)	160	110	150	145	148
Accuracy (mils RMS) + (Peak to Peak)	0.54 1.0	0.73 1.90	0.62 2.10	0.65 2.15	1.30 4.20

*Breadboard model only.

+At room temperature.

² Sperry Gyroscope, North-Seeking Gyrocompass, US Army Engineer Topographic Laboratories, Fort Belvoir, VA., ETL-0251, January 1981, AD-A100 036.

CONCLUSIONS

Based upon evaluations of current state-of-the-art technology along with the evaluation and testing of several miniaturized gyrocompass designs and demonstration models, the judgment is that a miniaturized gyrocompass can be developed which meets the design goals of:

Weight - less than 6 pounds

Size - less than 200 cubic inches

Response - less than 3 minutes

Accuracy - 1 to 3 mils RMS

There is sufficient data to suggest that certain performance characteristics can be improved since tradeoffs exist between accuracy, latitude of operation, gyrocompassing period (response time), and the associated costs of implementation for a selected configuration. Although vehicle testing with a miniaturized gyrocompass device was limited, it appears that such a device is capable of operation in a static vehicle with engine running. Again, as in any ground application, the performance of a vehicle-mounted device is dependent on the stability of the mounting platform, and any excursions about the vertical axis during the static mode would degrade performance. Because of its inherent design, the miniaturized gyrocompass will not perform correctly in a dynamic (moving) vehicle.